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April 25, 2008

**To:** Environmental Protection Agency  
Cincinnati Procurement Operations Division  
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Cincinnati, OH 45268

**Attention:** Ms. Tammy Thomas  
Contract Officer

**From:** Kevin Whitney  
Emissions Research and Development Department  
Southwest Research Institute  
P.O. Drawer 28510  
San Antonio, Texas 78228-0510

**Subject:** Work Plan for Amendments 5, 6, 7, and 8 of Work Assignment 0-01, EPA Contract EP-C-07-028, under SwRI Project 03.13363, SwRI Proposal No. 03-50782C.

Contract Title: "Testing and Related Support for Energy Bill-Mandated Activities"

Assignment Title: "Comprehensive Gasoline Light Duty Exhaust Fuel Effects Test Program to Cover Multiple Fuel Properties and Two Ambient Test Temperatures"

## 1.0 INTRODUCTION

As per Amendment 4.

## 2.0 TECHNICAL DISCUSSION

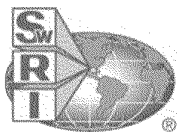
As per Amendment 4.

## 3.0 SCOPE OF WORK

As per Amendment 4 except as discussed below.

### 3.1 Work Plan Development

As per Amendment 4.



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### 3.2 Quality Assurance Project Plan and Quality Management Plan (QAPP/QMP)

As per Amendment 4.

### 3.3 Vehicle Recruitment

Table 1 reflects a change in the specifications for the Chevrolet Cobalt. All other items are per Amendment 4.

**TABLE 1. TEST VEHICLES FOR RECRUITMENT**

Year	Make	Brand	Model	Engine	Engine Family	T2 Bin	Note
2008	GM	Chevrolet	Cobalt	2.2L I4	8GMXV02.4025	5	
2008	GM	Chevrolet	Impala FFV	3.5L V6	8GMXV03.9052	5	
2008	GM	Saturn	Outlook	3.6L V6	8GMXT03.6151	5	FFV
2008	GM	Chevrolet	C1500 Silverado	5.3L V8	8GMXT05.3373	5	
2008	Toyota	Toyota	Corolla	1.8L I4	8TYXV01.8BEA	5	FFV
2008	Toyota	Toyota	Camry	2.4L I4	8TYXV02.4BEA	5	
2008	Toyota	Toyota	Sienna	3.5L V6	8TYXT03.5BEM	5	
2008	Toyota	Toyota	Tundra	4.0L V6	8TYXT04.0AES	5	
2008	Ford	Ford	Focus	2.0L I4	8FMXV02.0VD4	4	
2008	Ford	Ford	Taurus	3.5L V6	8FMXV03.5VEP	5	
2008	Ford	Ford	Explorer	4.0L V6	8FMXT04.03DB	4	
2008	Ford	Ford	F150 FFV	5.4L V8	8FMXT05.44HF	8	
2008	Chrysler	Dodge	Caliber	2.4L I4	8CRXB02.4MEO	5	FFV
2008	Chrysler	Dodge	Caravan FFV	3.3L V6	8CRXT03.3NEP	8	
2008	Chrysler	Jeep	Liberty	3.7L V6	8CRXT03.7NE0	5	FFV
2008	Honda	Honda	Civic	1.8L I4	8HNXV01.8LKR	5	
2008	Honda	Honda	Accord	2.4L I4	8HNXV02.4TKR	5	
2008	Honda	Honda	Odyssey	3.5L V6	8HNXT03.54KR	5	
2008	Nissan	Nissan	Altima	2.5L I4	8NSXV02.5G5A	5	

### 3.4 Test Lubricants

As per Amendment 4.

### 3.5 Test Fuels

The test fuels will be blended exclusively from refinery components and cuts of refinery components. Special chemicals and chemical blendstocks shall not be used. However, butane and benzene may be used to adjust RVP and benzene content of these fuels, respectively. The distillation properties of the test fuels should meet the following requirements:

- The segments of distillation curves between T<sub>10</sub> and T<sub>50</sub> should either be straight lines or slightly convex.

- The segments of distillation curves between T<sub>50</sub> and T<sub>90</sub> should be concave.
- T<sub>90</sub> minus T<sub>80</sub> should not exceed 50 °F and for nearly all fuels should be lower than 40 °F.

Additional effort is being made to ensure that the distillation curves of Fuels 18 and 19 are as similar as possible ( $\pm$  5°F preferred) to Fuel 17 from T<sub>50</sub> through T<sub>90</sub>. If necessary, new formulations of Fuels 18 and 19 will be blended. Any new fuel blending will affect project budget and schedule. It has been necessary for SwRI to visit with the fuel blender, Haltermann Products, in an attempt to resolve this matter. Additionally, an allocation has been made to accommodate potential blend iterations.

Upon the receipt of test fuels, SwRI will conduct a set of analyses as listed in Table 2, on a sample from a single drum of each fuel. Additional analyses (to be determined) will be conducted on a single drum sample of each fuel at the midpoint and at the end of the program to determine if any fuel properties have changed as a result of fuel storage and handling.

**TABLE 2. TEST FUEL ANALYSES**

<b>Fuel Property</b>	<b>Test Method</b>
Relative Density	ASTM D4052
Ethanol	ASTM D5599
Total Oxygenates Other Than Ethanol	ASTM D5599
Distillation	ASTM D86
DVPE	ASTM D5191
Aromatics	ASTM D1319
Olefins	ASTM D1319
Benzene	ASTM D3606
Sulfur	ASTM D5453
RON	ASTM D2699
MON	ASTM D2700
Hydrogen	ASTM D4808 Method A
Oxygen	ASTM D5599
Net Heat of Combustion	ASTM D4809 Also report C and H by ASTM D5291

To assure that no fuel drums are mislabeled, SwRI will confirm fuel properties listed in Table 3 using a Petrospec® analyzer each time a new drum is opened. Additionally, unique alphanumeric labels assigned to individual drums will be recorded each time a vehicle is fueled.

**TABLE 3. TEST FUEL PROPERTIES TO BE CONFIRMED  
USING A PETROSPEC® ANALYZER**

<b>Ethanol Content of the Fuel, vol. %</b>	<b>Fuel Properties to Be Confirmed</b>
0 – 15	Ethanol content, aromatic content, T90
> 15	Aromatic content, T90

A 5-gallon sample of each test fuel for shipment to the EPA, as well as fuel samples needed to perform the analyses listed in Table 3, will be taken from drums cooled below 45°F (preferably placed on their sides). Care will be taken to avoid splashing of the fuels during sampling by making sure that the filling tube reaches to the bottom of each container being filled.

### **3.6 Vehicle Preparation**

The exhaust systems of the test vehicles shall be tested for leaks. Weep holes in the mufflers will be plugged for the duration of the program.

Oil samples taken at 2,000 miles and all subsequent oil samples shall be shipped in biweekly batches to the following address:

Lubrizol Corporation  
1275 Lloyd Road (Bldg 8)  
Wickliffe, OH 44092  
Attn: Dr. Ewa Bardasz

Following the second oil change, no engine oil will be added to any test vehicle until the completion of the test program. Should engine oil level in any the test vehicle fall to the minimum mark on the dipstick anytime during this program, SwRI will immediately notify the EPA WAM.

Additional 4 oz. engine oil samples will be taken and shipped to Lubrizol following emissions testing of the 4th, 14th and 25th fuel in the Phase 3 test sequence of each vehicle, assuming that Fuels 1-16 and 20-28 will be tested in each vehicle as one set in a random order.

In the case of the four FFVs, the final oil sample will be taken following emissions testing on E85 fuel (the last fuel tested in each FFV in Phase 3 of the program). At that time the oil level on the dipstick will also be recorded.

All engine oil samples will be taken from warmed up engines, preferably using a vampire pump. The following information will be recorded in program files and on the oil sample label to be attached to each sample taken:

- Date
- Test vehicle designation
- Odometer miles

- Designation of exhaust emissions test immediately preceding engine oil sampling, if applicable
- Test oil code

Road load derivations to generate dyno set coefficients will be performed at 75°F once vehicles have completed mileage accumulation. The equivalent test weight (ETW) and target coefficients for each vehicle must be approved by the EPA WAM. For the purpose of this study, the agreed road load settings will remain the same for all testing on a given vehicle including the cold temperature testing.

### **3.7 Vehicle Testing**

During tests performed at FTP ambient conditions, intake air temperature and humidity will be maintained at  $75 \pm 2^\circ\text{F}$  and  $75 \pm 5$  grains  $\text{H}_2\text{O}/\text{lb}$  dry air, respectively. During tests performed at  $50^\circ\text{F}$ , intake air temperature will be maintained at  $50 \pm 2^\circ\text{F}$ . SwRI will recommend the intake air humidity setting and tolerance for  $50^\circ\text{F}$  emission tests which must be approved by the WAM before  $50^\circ\text{F}$  testing can begin.

Due to a requested change in the fuel change and vehicle preconditioning sequence, SwRI now anticipates testing 24 vehicles per week at room temperature and four (4) vehicles per day at  $50^\circ\text{F}$ . Tests will be conducted 5 days per week. Testing will be conducted during one shift while vehicle preparation and preconditioning will be conducted during a second shift. We expect that the test cell will be available for 48 weeks in a given 52-week period, resulting in an average test cell throughput of 22 vehicles per week at room temperature, and 18 vehicles per week at  $50^\circ\text{F}$ . This level of effort will require some overtime from core laboratory staff. An allocation for premium pay, as well as the inclusion of a shift differential, has been included in the attached budget.

The attached budget assumes that SwRI will conduct 114 room-temperature tests and no more than 50 percent of the tests at  $50^\circ\text{F}$  during the first year of the contract. This schedule is contingent on the receipt of Fuels 17, 18, and 19 in a timely manner. If the delivery and approval of test fuels is delayed beyond the beginning of April 2008, it will not be possible to conduct all expected tests in the first year of the contract, and a revision to the first-year budget will be necessary.

#### **3.7.1 Fuel Change and Test Execution Sequence**

The fuel change and vehicle preconditioning sequence (Table 3) has been changed as follows:

- Any previously-opened drum of test fuel will be stored below  $50^\circ\text{F}$ .
- Step 5 has been added to Table 3.
- Step 7 has been added to Table 3.
- The preconditioning cycle will now be a cold-start 3-phase LA92 (Step 8).

**TABLE 3. FUEL CHANGE AND TEST EXECUTION SEQUENCE**

<b>Step</b>	<b>Description</b>
1	Drain vehicle fuel completely via fuel rail whenever possible.
2	Turn vehicle ignition to RUN position for 30 seconds to allow controls to allow fuel level reading to stabilize. Confirm the return of fuel gauge reading to zero.
3	Fill fuel tank to 40% with next test fuel in sequence. Fill-up fuel must be less than 50°F for all three Phases of the test program.
4	Start vehicle and execute catalyst sulfur removal procedure described in Appendix C of CRC E-60 Program report. Engine oil temperature in the sump will be measured and recorded during the sulfur removal cycle.
5	Four vehicle coast downs from 70 to 30 mph shall be performed with the last two measured and monitored in Phases 1 and 2 to establish tolerances for each vehicle for use in Phase 3. During Phases 1 and 2, a vehicle's average coastdown time from an individual fuel change sequence will be compared to the average of all coastdown times for that vehicle. If the individual run deviated from the overall average by more than $\pm 5\%$ , the vehicle will be checked for any obvious and gross source of change in the vehicle's mechanical friction. The results obtained during Phases 1 and 2 will be used to establish repeatability criteria to be used during Phase 3.
6	Drain fuel and refill to 40% with test fuel. Fill-up fuel must be less than 50°F for all three Phases of the test program.
7	Soak vehicle for at least 12 hours to allow fuel temperature to stabilize to the test temperature.
8	Move vehicle to test area without starting engine. Start vehicle and drive one 3-phase LA92 cycle.
9	Move vehicle to soak area without starting or driving.
10	Park vehicle in soak area at proper temperature (75 or 50°F) for 12-36 hours.
11	Move vehicle to test area without starting engine.
12	Perform LA92 cycle emissions test.
13	Park vehicle in soak area of proper temperature for 12-36 hours.
14	Move vehicle to test area without driving.
15	Perform LA92 emissions test.
16	Determine whether third replicate is necessary, based on data variability criteria (see Table 2).
17	If a third replicate is required, repeat steps 13, 14 and 15.
18	If third replicate is not required, return to step 1 and proceed with next fuel in test sequence.

### **3.7.2 Test Sequence**

The emission test program will be executed in the following sequence:

- Phase 1: Fuels 17, 18 and 19 tested in all vehicles at 75°F
- Phase 2: Fuels 17, 18 and 19 tested in all vehicles at 50°F
- Phase 3: Fuels 1-16 tested in all vehicles at 75°F

In Phases 1 and 2 of the program, the test fuels will be tested in each vehicle in the following sequence: Fuel 17 (E0) followed by Fuel 18 (E10) and then Fuel 19 (E15).

It is expected that Phase 1 testing will begin in April 2008. SwRI anticipates being able to complete all of Phase 1 during the first year of the contract.

Following completion of Phase 1, it is expected that approximately three weeks will be needed to prepare for Phase 2 testing at 50°F. Pending successful installation and operation of the equipment necessary to conduct testing at 50°F, SwRI anticipates being able to complete no more than 50 percent of Phase 2 during the first year of the contract. The remainder of Phase 2 will be completed in the second year of the contract.

It is expected that Phase 3 will begin approximately two weeks following the completion of Phase 2. Assuming Phases 1 and 2 are completed as expected, SwRI anticipates that Phase 3 testing of Fuels 1 through 16, could be completed in August 2009, assuming that Fuels 1-16 and 20-28 will be tested in each vehicle as one set in a random order.

SwRI will ensure that sample flow proportionality is verified after each emission test. For PM samples, a proportionality statistic will be calculated and reported. For other emissions, SwRI will verify that the tunnel flow remains constant during a test. The CVS blower will be kept on for approximately 20 minutes before the first emission test on a given day and continuously between emission tests to ensure tunnel stability.

SwRI will ensure consistent cooling fan placement and flow for each test vehicle on all the tests. The flow of air sweeping the vehicle in the test cell will be as consistent as is practical for all test conducted at either 50°F or 75°F.

SwRI will identify external test data that can be used as an additional diagnostic to track changes in the analytical and sampling systems used in this program. Proprietary information will be “sanitized” prior to reporting to EPA. Data will include the current CARB laboratory correlation program.

SwRI will conduct “blank” LA92 tests periodically during Phases 1, 2 and 3 of this program. These tests will involve running the full test sequence drawing only background air into the sampling system. All sampling systems will be operated and measurements will include:

- Phase level THC, CH<sub>4</sub>, CO, NO<sub>x</sub>, CO<sub>2</sub>, PM, ethanol by INNOVA, NO<sub>2</sub>, VOCs (including aldehydes and alcohols)
- Continuous THC, NMHC, CO, NO<sub>x</sub>, CO<sub>2</sub>, N<sub>2</sub>O, NH<sub>3</sub>, and HCN

Two such tests, spaced one week apart, will be performed at the outset of Phase 1 followed by another test one month later. One “blank” LA92 test shall be conducted at the start of Phases 2 and 3 followed by additional such tests at one month intervals. A separate cost estimate for these tests has been provided below in Section 6.



### ***3.7.3 Determination of Phase Level and Continuous Regulated Emissions***

The unweighted, integrated mass emissions by phase and for the entire test for the continuous THC, NMHC, CO, CO<sub>2</sub>, NO<sub>x</sub>, will be compared to the mass emission values measured by the mechanically integrated (bag) CVS samples. For only the unweighted, integrated mass emissions for the entire test, the following maximum deviations from the CVS measurements will be used as guidelines until appropriate criteria are developed in Phase 1 of the program:

- THC:           ±15%
- NMHC:       ±15%
- CO:           ±10%
- CO<sub>2</sub>:       ±5%
- NO<sub>x</sub>:       ±10%

Additionally, available data will be acquired at least 1 Hz from each vehicle's onboard diagnostic (OBD) system during all emissions tests using a DBK70 data acquisition system. The available data are expected to include:

- RPM
- Vehicle speed
- Engine load
- Short term fuel trim-bank 1
- Long term fuel trim-bank 1
- MIL status
- Absolute throttle position
- Engine coolant temperature
- Short term fuel trim-bank 2
- Long term fuel trim-bank 2
- Fuel/air commanded equivalence ratio
- Alcohol fuel percent
- Manifold absolute pressure
- Spark advance
- PID \$42 Control Module Voltage
- Purge

It should be noted that some of the parameters listed above may not be accessible for specific vehicles.

### ***3.7.4 Speciation of Volatile Organic Compounds***

Phase-level (bag-by-bag) speciated VOCs will include C<sub>1</sub>-C<sub>12</sub> hydrocarbons as well as light alcohols, aldehydes, and ketones. Sampling and analysis of C<sub>2</sub>-C<sub>12</sub> hydrocarbons will be conducted in a manner similar to CARB method 1002/1003, "Procedure for the Determination of C<sub>2</sub>-C<sub>12</sub> Hydrocarbons in Automotive Exhaust Samples by Gas Chromatography". Sampling and analysis of alcohols will be done using a method similar to CARB method 1001, "Determination of Alcohols in Automotive Source Samples by Gas Chromatography". Sampling and analysis of

carbonyl compounds will be conducted in a manner similar to CARB method 1004, "Determination of Aldehyde and Ketone compounds in Automotive Source Samples by High Performance Liquid Chromatography". Analysis of C<sub>1</sub> – C<sub>4</sub> HC samples will be done within one hour of completion of the emissions test. Subsequent analysis of the additional compounds of interest will be done within 4 hours of emission test completion. The time between sample collection and the start of C<sub>1</sub>-C<sub>4</sub> HC analysis will be reported. The VOCs to be analyzed are identified in Appendix D of the Statement of Work.

During the analysis of C<sub>2</sub>-C<sub>4</sub> hydrocarbons, special consideration will be given to 1,3-butadiene. Because of the instability of 1,3-butadiene, the analysis of C<sub>2</sub>-C<sub>4</sub> hydrocarbon samples collected during phase 1 of the test cycle shall be initiated within one hour of collection. The speciation of C<sub>5</sub>-C<sub>12</sub> hydrocarbon samples collected in phase 1 of the test cycle will be completed within 4 hours of collection. The time between sample collection and the start of C<sub>2</sub>-C<sub>4</sub> and C<sub>5</sub>-C<sub>12</sub> hydrocarbon analysis will be recorded. SwRI will make a good-faith effort to complete the analysis of C<sub>2</sub>-C<sub>4</sub> and C<sub>5</sub>-C<sub>12</sub> background hydrocarbon samples on the day they are collected.

Alcohol samples will be sealed and stored at a temperature below 40°F immediately following collection. A good-faith effort will be made to analyze these samples on the day they are collected, but no later than within six calendar days.

Samples of carbonyl compounds will be collected in cartridge type samplers. These samples will be extracted immediately following collection (within 15 minutes) and the extracts sealed and stored immediately at a temperature below 40°F. A good-faith effort will be made to analyze these extracts on the day they are collected, but no later than within three calendar days. This analysis will account for the presence of acrolein-x in the sample. The location of the acrolein-x peak in the HPLC chromatogram will be determined and, using the response factors derived from the calibration for acrolein, acrolein-x mass emissions will be quantified and reported.

The following daily sequence will be used for vehicle testing:

- All vehicles requiring VOC sampling only during phase 1 (Bag 1) of the test cycle will be tested first.
- Any vehicle requiring VOC sampling during all three phases of the test cycle will be tested last. No more than one such vehicle will be tested per test day unless the total number of vehicles tested on that day and the timing of their tests will not compromise the time limit requirements for sample analyses.

The following daily sequence will be used for the analysis of VOC samples:

- VOC samples collected in phase 1 of the test cycle will be analyzed first, in the sequence of vehicle tests.
- If a vehicle requiring VOC sampling during all three phases of the test cycle is tested, the phase 1 sample will be analyzed first, followed immediately by the phase 3 sample and finally by the phase 2 sample.
- Background samples will be analyzed last, in the sequence of vehicle tests.

### **3.7.6 Continuous Measurements of $N_2O$ , $NH_3$ and HCN**

Continuous and phase-integrated emissions of  $N_2O$ ,  $NH_3$  and HCN will be measured using Fourier Transform Infrared Spectroscopy (FTIR) during Phases 1 and 2 of the program, and during E85 tests on four FFVs tested in Phase 3 of the program. These measurements will only be taken during the first test of each fuel/vehicle combination and no repeat measurements will be conducted.

## **4.0 REPORTING AND DELIVERABLES**

### **4.1 Weekly Reports**

SwRI will provide 30-60 minute telephone conference reports weekly that summarize progress to date. Weekly test results in spreadsheet form shall be provided to the EPA WAM.

The oral report will indicate progress achieved in the preceding week, technical issues encountered, solutions to issues (proposed or attempted), and projected activity in the following week. This report will include any potential issues or circumstances that arise causing any delays in the testing.

SwRI will provide on a weekly basis to the WAM a report summarizing hours and dollars expended for individual tasks. The goal of the report is to identify as early as possible if costs in hours and dollars are exceeding that which has been budgeted for the program

### **4.2 Monthly Written Progress Reports**

As Per Amendment 4

### **4.3 Data Files**

As Per Amendment 4

### **4.4 Mode of Delivery**

As per Amendment 4.

### **4.5 Draft Final Report**

As per Amendment 4.

### **4.6 Final Report**

As per Amendment 4.

## 5.0 STAFF ASSIGNMENTS

As per Amendment 4.

## 6.0 PROJECTED LABOR HOURS AND OTHER DIRECT COSTS

Based on our understanding of Amendments 5, 6, 7, and 8 to Work Assignment 0-01, we project the breakdown of employee utilization by labor category as detailed in Table 4 for the first year of the contract. Complete cost detail for the first year's effort is presented in the attached cost breakdown shown in Appendix A. Table 5 contains cost estimates for the budget impact of individual items added during Amendments 5, 6, 7, and 8.

**TABLE 4. PROJECTED LABOR HOURS FOR AMENDMENT 8 TO WORK ASSIGNMENT 0-01; FIRST YEAR OF CONTRACT**

Labor Category	Number of Hours
PL4	<b>Ex. 4 - CBI</b>
PL3	
PL2	
PL1	
Senior Technical	
Technical	
Clerical	
Total	
Total Technical Hours	

**TABLE 5. BUDGETARY COST ESTIMATES FOR ADDITIONAL EFFORT SPECIFIED IN AMENDMENTS 5, 6, 7, & 8**

	Amendment 5	Amendment 6	Amendment 7	Amendment 8
Year 1	<b>Ex. 4 - CBI</b>			
Total Program				
Change in Fuel Price (Phase 1)				
Add FTIR to Phase 2				
Add FTIR to Phase 3				
Cartridges for Aldehydes				
Acrolin x Setup				
Blank LA 92 Tests				
Additional Budgetary Reporting				
Visit Haltermann (Phase 1)				
Fuel 18 Iteration 3 (Phase 1)				
Fuel 18 Iteration 4 (Phase 1)				
External Correlation data (Phase 1)				
Coastdowns				
Battery Chargers				
LA92 Instead of LA4				
RVP checks (Phase 1)				

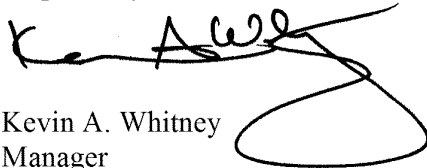
## 8.0 EXCEPTIONS

As per Amendment 4.

## 9.0 SUMMARY

Southwest Research Institute has responded to Amendments 5, 6, 7, and 8 to Work Assignment 0-01 with exceptions as noted in Section 8.0 above. Should any questions of a technical nature arise, please contact Mr. Kevin Whitney at 210-522-5869 or Mr. Patrick Merritt at 210-522-5422. If there are questions regarding cost or contractual issues, please contact Ms. Sherry Twilligear at 210-522-3948. Thank you for this opportunity to be of service.

Prepared by:



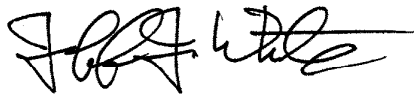
Kevin A. Whitney  
Manager  
Light-Duty Vehicle Emissions

Reviewed and submitted:



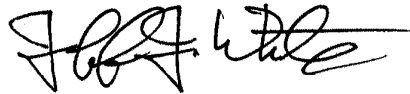
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Mr. Carl Fulper, EPA-AA  
Ms. Sherry Twilligear, SwRI Contracts

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## **APPENDIX A**

### **COST DETAIL FOR AMENDMENTS 5, 6, 7, AND 8 TO WORK ASSIGNMENT 0-01**

**Ex. 4 - CBI**

# Ex. 4 - CBI



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